# SEGREGATION GRANITES

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The deposits of asbestus of the Eastern Townships in Canada are the most exploited of the world. In 1919 $18,000,000 worth or 3,082,384 tons were mined. This means a great deal of development and has given J. W. Dresser, the geologist who has for years followed the region with the closest attention, a chance to make observations which are of general theoretical interest. Fifteen years ago[1] Dresser suggested that certain granites seemed to have been differentiated from the same magma from which were derived the serpentines in which the veins of asbestus chrysotile occur. This would tend to support Daly's idea[2] that granite is a product of differentiation from a basaltic substratum, *but not necessarily that it is "syntectic,"* that is, due to previous assimilation of something like a quartzite.

Some twenty years ago I had occasion to study with critical care what I then called "acid interstices" which practically always occurred near the middle of every diabase dike of over ten meters thickness or so.[3] I had over two hundred thin sections, and while Bayley and Irving and Wadsworth were inclined to believe the interstices filled with micropegmatite were secondary, I was inclined to agree with A. C. Lawson in believing them primary. By a careful study I convinced myself that such was the case. Later studies showed that the filling of similar interstices in effusive rocks was characteristically different, and I called the effusive texture doleritic. The conception I gathered was that these

[1] See *Bull. Geol. Soc. Am.*, Vol. XVII, p. 510; also *Canadian Survey Memoir*, Vol. XXII, and other papers by Dresser given in Ferrier's finding list.

[2] *Igneous Rocks and Their Origin*, p. 361.

[3] *Geological Survey of Michigan*, Vol. VI (1899), pp. 235–42, the work was largely done in 1890; see *Report of the State Board of Geological Survey of Michigan for the Years 1891 and 1892*, p. 177.

cavities were "filled with the residuum of the molten magma. Enough of the rock was formed to make it perfectly solid, for no further motion could take place without disturbing the micropegmatite borders of the felspar laths and fracturing the excessively delicate apatite needles. The remaining interstices seem, agreeing with the general law of increasing acidity in residual magmas, to have been filled with the final concentration of an acid aqueo-igneous magma which had been corroding the olivine and forming the less basic augite from it. In this magma were also concentrated the absorbed gases, aqueous and otherwise, which the dike margin originally contained and which, as the dike solidified at the margin, would probably be driven from it and concentrated at the center.

"The acid magma thus left seems to have proceeded to produce brown hornblende upon and out of the augite; brown mica upon and out of the iron oxides, as Smyth has suggested; and pegmatite growths on or out of the feldspar, while apatite needles formed across the cavities." The convincing arguments were that these interstices did not occur in marginal sections, and showed no signs of being more abundant in uralitic sections, but were best developed in otherwise fresh dikes, and were not present with superficial textures such as the amygdaloid textures.

The facts I have seen in the Medford diabase and elsewhere in the intervening thirty years have only strengthened the conviction that this interpretation is substantially correct, though it should be expressed not so much in terms of acid and basic, as in terms of those eutectic lines and troughs which the geophysical laboratory at Washington has worked out, the theoretical bearing of which has been developed by N. L. Bowen.[1]

The fluid magma from which the minerals of these interstices crystallized out would be closely held by capillarity if they were not large. But with increasing coarseness and size of interstices there would be more chance for it to drain out like honey from the honeycomb, or as Bowen and Harker have suggested, be squeezed

[1] "The Problem of the Anorthosites," *Jour. Geol.*, Vol. XXVIII (1919), pp.393–434; *ibid.*, Vol. XXV, 3 (1917), pp. 210–44, "Crystallization—Differentiation in Igneous Magmas," and literature there cited; *Am. Jour. Sci.* (1915), p. 407; (1914), p. 207, etc.

out like fluid from a filter press. When this happens we have the aplitic red rock associated with the Duluth Gabbro described most fully and lately by F. F. Grout[1] or with that of Mount Bohemia, so fully described by F. E. Wright.[2] If one supposes this segregation conducted on a still larger scale or so that the crystallization shall be somewhat coarser and the grain coarser, the logical outcome would be a granite. This is just what Dresser finds that the advance of mining operations has conclusively proved[3] by showing that masses of granite have no separate connection with the earth's interior.

The largest mass of differentiated hornblende granite mentioned by Dresser is three-quarters of a mile long by one-quarter of a mile wide, with a coarser pegmatite border two or three feet wide and a porphyritic texture throughout. This granite "is an indication rather than a cause" of the presence of acid waters in the magmatic residue needed to produce serpentine and asbestos. It is interesting to note that Bowen starting with peridotite as a monomineralic differentiate suggested that the region "may" furnish a "complementary granitic differentiate." He is apparently right!

Now the laws of physics and chemistry are universal. If this has happened in the Lake Superior region and the Eastern Townships it must have happened in many other places. One is tempted to consider the Mull pitchstones[4] the "leidleites and inninmorites" which (*a*) apparently occur only as intrusions, (*b*) are high in primary water, (*c*) are glassy at the center and stony at the sides, i.e., coarser at the margins, as representing such a magma as that of the red rock of Wright, of Grout, etc., chilled more quickly and without loss of water, but yet like many aplites or the granite described by Dresser, consolidating more slowly at the margin. This I have shown is more likely to happen when the initial magma tem-

[1] "A Type of Igneous Differentiation," *Jour. Geol.*, Vol. XXVI (1918), p. 618.

[2] *Report Michigan Geological Survey* (1908), p. 387.

[3] "Granitic Segregations in the Serpentine Series of Quebec," *Transactions of the Royal Society of Canada* (1920), pp. 7–13. Compare also N. L. Bowen, "Differentiation by Deformation," *Proc. Nat. Acad. Sci.* (1920), p. 160.

[4] E. M. Anderson, and E. G. Bailey, *Quart. Jour. Geol. Soc.*, Vol. LXXI (1916), pp. 205–16, London.

perature is low. In other words they are "secundine"[1] to the great series of basalts and gabbros.

The primary water-content (exceeding the average for rocks of similar composition) which Anderson and Bailey emphasize as characteristic is very suggestive. The analysis (1) of the glassy part of the leidleite may be very nearly that of the anchieutectic solution that once filled the acid interstices and that wandering off by itself would make red rocks and even hornblende granites. That though central it is glassy may be due partly to great viscosity and less power of crystallization, due to less lime, iron, and magnesia, and more silica, partly to a more rapid passage through the crystallization range of temperature, even though later.

If we study these analyses (see following table), 1 and 2 given by Anderson and Radley, and compare with 3 and 4, Bowen's analyses of Canada diabase and dike granite and with the average igneous rock as given by Clarke and Daly we find, (1) that they are not very far from the average igneous rock, (2) that they are not very far from the eutectic trough or line to which I called attention in 1904,[2] (3) that they are not very far from the analyses of the red rocks given by Grout and Wright, etc., (4) that the

[1] I have found the following classification of dikes with the appropriate adjectives to have some value:

1. *Invasive.*—Forced more or less slowly into cavities formed by the extra hydrostatic pressure of the invading magma; contacts irregular and often close-welded.

2. *Suctive.*—Forced quickly into a crack otherwise opened, by fault or earthquake relieving strain, aided by gravitative suction, owing to the condensation by cooling of the gases from the magma; contacts generally fairly straight and not close-welded.

Nearly parallel is a classification according to the hot or cold condition of the country rock as follows:

1. *Secundine* (Latin *secundine*=afterbirth).—Injected into a hot country rock; contact generally irregular, close-welded, the grain generally equal throughout, either finer or coarser at or near the margin.

A characteristic mode of occurrence of lamprophyres, aplites and pegmatites.

2. *Subsequent.*—Injected into a cold country rock, with fine-grained selvages (the zones of increasing grain amounting to from one-quarter to one-tenth of the breadth of the dike) with straight and not close-welded contacts.

A characteristic occurrence of dikes not closely connected with larger masses or volcanic centers, and in composition close to Bunsen's normal basaltic magma or more basic.

The anchieutectic rocks which we are discussing are generally invasive secundine, but in case of shrinkage cracks, due to loss of heat or contact metamorphism, may be suctive and secundine too.

[2] *Jour. Geol.*, (1904), p. 91. See also *Wet and Dry Differentiation*, "Tufts College Studies," Vol. III, Pt. I.

stony margin (An.2) in its less silica, more lime and magnesia is not so far on the toboggan slide toward the goal of "wet differentiation"—the magma from whence crystallizes pegmatite veins, and not so near to a granite (An. 4) as the glassy center (An. 1). We seem thus to have caught two stages in a differentiation which carried on on a large scale would lead to the hornblende granites described by Dresser.

As to the syntexis upon which Daly lays stress, there is no doubt that the inclusion and absorption of fragments of sandstone, *especially if they contained water in the interstices*, should promote the formation of micropegmatite, and zones of micropegmatite around such fragments in process of absorption are found in the Medford diabase, as Jaggar and others have seen. Possibly the water is quite as important as the silica. Very likely much of the red rock of Pigeon Point is of this nature. But the association of micropegmatite with diabases is too widespread for me to agree with Daly[1] that most granites are differentiates of syntectics. It is well worth considering how many are, like that described by Dresser, direct differentiates with the help of juvenile juices or mineralizers.

| Oxides | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| | Glassy Central Leidleite | Stony Marginal Leidleite | Diabase Cobalt | Granite from Cobalt |
| $SiO_2$ | 61.69 | 59.21 | 50.12 | 72.33 |
| $TiO_2$ | 1.00 | 1.06 | .55 | .74 |
| $Al_2O_3$ | 14.43 | 14.06 | 15.70 | 12.99 |
| $Fe_2O_3$ | 1.23 | 2.66 | 1.42 | none |
| FeO | 5.86 | 4.87 | 6.89 | 2.50 |
| MnO | 0.30 | 0.24 | ..... | ..... |
| CaO | 4.97 | 5.95 | 11.30 | 1.73 |
| MgO | 2.81 | 3.71 | 9.50 | 0.97 |
| $Na_2O$ | 3.20 | 2.06 | 2.91 | 7.60 |
| $K_2O$ | 1.72 | 2.83 | 1.07 | ..... |
| BaO | 0.04 | 0.03 | none | ..... |
| $H_2O$ at 105° C. | 0.25 | 2.05 | 1.03 | 1.09 |
| $H_2O$ above 105° C | 2.36 | 1.54 | 0.21 | ..... |
| Total | 100.12* | 100.47 † | 100.84 ‡ | 100.95 § |

* Including 0.02 Cl. 0.24 $P_2O_5$ † Including 0.2 $P_2O_5$.

‡ Bowen in *Can. Mining Inst.*, Vol. XII (1909), p. 523, diabase, including 14 S.

§ *Ibid.*, granite cutting diabase, including 1.00 $CO_2$.

[1] *Op. cit.*, p. 312, etc.

## ERRATA

*Journal of Geology*, Volume XXX, on page 164, line 2 from the bottom, and page 165, line 2 from the top, read Radley, instead of "Bailey."